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Report

Covering Plan of Proposed Improvements

BOSQUE DEL APACHE MIGRATORY WATERFOWL REFUGE

Socorro County, New Mexico

By

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INTRODUCTORY

The Bosque del Apache Grant, a Spanish Land Grant comprising approximately 53,000 acres and located about 15 miles south of Socorro, New Mexico, is the land proposed for inclusion in the Bosque del Apache Migratory Waterfowl Refuge. It has never been subdivided except for a small acreage in the southeast corner. The Bureau of Biological Survey of the United States Department of Agriculture proposes to acquire the entire grant and convert it into a Federal refuge, primarily for waterfowl. This report is limited to a consideration of the waterfowl phase of the proposed project and includes a complete discussion of the plan of development.

Location and Extent of Waterfowl Area

The part to be developed for waterfowl will lie within the river valley and will extend from the north to the south boundary of the Grant. The tract is bisected from north to south by the Rio Grande, which varies in width from a maximum of 2,000 feet to a minimum of 400 feet. The western half of the tract also is bisected from north to south by the Santa Fe Railroad and U. S. Highway No. 85.

The proposed migratory waterfowl refuge includes an area of 14,060 acres divided as follows:

1.	West of U. S. Highway No. 85 and west of the Santa Fe Railroad right-of-way:-		
	(A) Between north line of Grant and Railroad Mile Post 999	1460	acres
	(B) Between south line of Grant and Railroad Mile Post 999	40	acres
2.	Lands within right-of-way, Highway No. 85	90	acres
3.	Lands within right-of-way, Santa Fe Railroad	120	acres
4.	East of Railroad and west of Rio Grande	6140	acres
5.	Lands assigned to Middle Rio Grande Conservancy District within Grant	210	acres
6.	River bed within present banks	2580	acres

7. East of Rio Grande:-

(A)	Small parcels in north extremity	800	acres
(B)	Large area of Bosque (optioned)	2150	acres
(C)	Private subdivisions	470	acres
	Total river Bottom lands within Grant	14,060	acres

It is proposed to exclude from consideration the small tracts of land lying to the south on the west side of the river and to the north on the east side of the river; likewise the 210 acres which were assigned to the Middle Rio Grande Conservancy District, also the river-bed area: and confine the development to the 7,600 acre tract on the west side of the river and the 2,620 acre block on the east side, both of which lie in a more or less compacted form. The strip to be allotted to the river-bed will be greatly widened thus reducing the net area of the refuge still further. (See detailed summary in Supplement to this report.)

General Conditions in Refuge Area

The natural surface of the land in both of the tracts where development is to be concentrated is ideal for the purpose intended, except for the presence of an excessive amount of timber. The topography is extremely irregular, but this is an advantage since the natural lowlands can be devoted exclusively to impounding water and producing aquatic foods for waterfowl, and the natural highlands can be reserved as nesting grounds and for the production of grains and other foods for reserve in time of shortage during the winter months. Although the records indicate freezing weather at various times, continued spells of extremely low temperatures are unknown in this region. Water coming from the deep drains will never freeze over, even in the coldest weather, and a relatively large area of open water will be maintained in the ponds during the late fall, winter, and early spring when the evaporation rate is low. This water acreage combined with the extensive acreage of upland foods will make of the Bosque del Apache a very attractive wintering ground for migratory waterfowl.

Proposed Plan of Development

A tentative plan of development for the area has been worked out. This plan is subject to such minor modifications in design or location as may be found necessary when final plans for the works are made prior to construction. The following improvements are planned:

1. To construct levees along the river banks in proper position to keep river floods out of the area.

2. To provide protection for the levees against scour and to provide means for easily and automatically building up the levees in the future to keep pace with rise of river bottom.

3. To excavate a system of drain ditches within the area in such a manner as to bring ground water into the lower portions.

4. To take advantage of the spoil from drain ditch excavation to build a system of interior dikes which will subdivide the area into a series of pools, marshes, and agricultural land.

5. To clear trees and brush from the portions of refuge which it is proposed to cover with water or to cultivate.

6. To provide a system of gates in the various dikes for controlling water levels and for draining the units as desired.

7. To provide gates, culverts and canals for use in diverting a certain amount of water from the Rio Grande River to the area for agricultural purposes. Water filings are being acquired with the property.

Relation of Rio Grande River to Refuge

A careful study of surface conditions reveals the fact that the river-bed is higher than the surface of the land on either side. In many cases it is 4 feet higher than the main body of the land on a line perpendicular to the axis of the river. Records indicate that the bed of the river is steadily rising, although it has an average gradient of more than 4 feet per mile. These statements are verified by accompanying maps and profiles.

One of the greatest hazards to the future of the proposed refuge is the danger of overflow from the meandering river during times of high water and of torrential flood. As a safeguard against such a hazard, it is proposed to allocate a strip of land at least 2,000 feet wide to the meanderings of the river and to build a high levee on either side as a protection against overflow. The levees are to be protected by jetties of rock, bound in heavy combination wire and by a fence of living black willows running parallel to the river and situated between the river and the levee. It is also proposed to deposit a heavy embankment of silt between the protecting fence and the levee and to encourage a dense growth of black willows on the strips of new land between the border fences and the levees.

Most of the area which it is proposed to develop is already subject to flooding by the river, and if left to the natural course of events it is safe to predict that the river would occupy, at some time or another within the next 10 years, the majority of the lands where development is proposed. Other isolated tracts such as the small coves which are being excluded would be flooded by stagnant pools of seepage water such as those which now exist within the town limits of San Marcial. (See series of accompanying photographs.) In this event it is estimated that the area of open water together with that which would produce plant growth that transpires an excessive amount of water would exceed the area which it is now proposed to maintain as open water and in useful aquatic growth. If the river were allowed to run wild as it is doing throughout most of its course from the Bosque del Apache to the upper reaches of the Elephant Butte reservoir, the area of wet and swampy land on either side would grow up very quickly to cat-tails and other aquatic and marsh weeds which are extravagant users of water and are worthless as food for waterfowl.

Under such conditions the water areas would be clogged by these marsh weeds with a corresponding reduction of open water or water which might be devoted to the production of food plants. Through the planned program of refuge management the aquatic plants grown will be kinds which use much less water, produce food and nesting cover for the ducks, and do not fill the ditches and ponds. It is evident that the uncontrolled meandering of the river would result in greater instability of water surface and would develop large areas of marsh which would have no drainage outlet to the river because of the fact that the river has the habit of building its stream-bed to a higher elevation than the adjacent lands, particularly if they are somewhat removed from the natural course of the stream. In short, it is concluded that a properly developed plan for handling the Bosque del Apache project may result in a saving to the river in total water consumption rather than in an increased use as has been suggested by some of the users located on the Rio Grande below the Elephant Butte reservoir.

The agricultural lands will be drained and the water thus recovered will be concentrated over a limited area of natural lowland. The surplus will be returned to the river. Likewise the surplus water from irrigation of agricultural crops will find its way into the lowlands, thence into the river.

Water Rights Attached to Property

It is proposed to devote at least one half of the lands within the boundaries of development to the production of agricultural crops and other vegetation of value as food and cover for waterfowl. Some of these crops will require a reasonable supply of irrigation water. Provision has been made for taking care of these requirements by making proof on a water filing which is being acquired with the property, and which is one of the most important considerations in the transaction. This filing for diversion from a point on the Rio Grande near the west end of the highway bridge at San Antonio calls for 97 cubic feet of water per second or such portion thereof as may be used beneficially for the irrigation of agricultural crops, including native grasses and similar vegetation of value for pasture, hay, or cover for game during the nesting season. Water filing No. 3 for 286 cubic feet per second is also in good standing on the State Engineer's books, and is intended for the irrigation of bench lands within the Grant. These lands will be developed for the production of food and cover for upland game on the bench lands lying back from the river valley, and will also be a valuable addition to the feeding grounds for migratory waterfowl. The irrigation of these bench lands will also supply some seepage water to the lower lying part of the refuge.

Water Filing

In making proof of the water filing it is proposed to include the lands on both sides of the river which are naturally adaptable to the production of agricultural crops. A statement to this effect is being filed with the State Engineer at Santa Fe, designating the areas which it is proposed to include in the proof of completion of works and the proof of beneficial use, with the request that permission be granted for making the proofs as indicated.

Another request is being filed with the State Engineer for the privilege of changing the point of diversion. It is proposed to obtain the water for irrigation of the agricultural area from the Conservancy District's lateral which enters the tract near the northwest corner of the Refuge just east of the railroad, rather than from the point indicated in the original filing at the head of the Elmendorf canal. It is also proposed to obtain a supplemental supply of irrigation water from the Conservancy District's drain, which enters the project a short distance east of the irrigation lateral. The officers of the Conservancy District have approved this procedure with the proviso that the District be given credit by the Tri-State Compact Commission for the volume of water delivered to the intakes of the Refuge canals.

Status of Water Filings

The right is claimed to make proof of beneficial use under water filing No. 2 for 97 cubic feet per second or such portion of that amount as may be required for the economic irrigation of the units designated as agricultural land, by virtue of the fact that the filing is one of the first of record on the State Engineer's books, and it antedates by 20 days a similar filing recorded by the Bureau of Reclamation for the storage of water in the Elephant Butte Reservoir. A similar right is claimed to make proof on Filing No. 3 for 286 cubic feet per second which was made at the same time as Filing No. 2. Under this filing it is proposed to divert a volume of 286 cubic feet per second for the irrigation of 20,000 acres of land on the east side of the river, including the bench lands south of the north boundary of Bosque del Apache Grant. The transaction of land acquirement carries with it the right to the amount of water under this filing which can be put to beneficial use. If permission is granted for making proof, the major part of the water would be used on the higher ground since Filing No. 2 will take care of the agricultural lands which it is proposed to develop on both sides of the river under the plans as outlined. The value of these filings was one of the chief considerations in the negotiations leading to the purchase of the Bosque del Apache Grant. Without this water which is necessary for the production of winter food for ducks, the project would have very little value as a migratory waterfowl refuge and would not warrant the expense incidental to its development.

It is believed that the Elephant Butte Reservoir has contributed to the river hazard with which the project is confronted by causing an unnatural rate of increase in the elevation of the river bed. This calls for an outlay for the protection of the refuge lands to be developed which in itself is more than the project would be worth without the large acreage of food crops which can be grown on the protected agricultural lands under an adequate system of irrigation. In this connection it is also maintained that the water-right claimed takes precedence over the new development in the Middle Rio Grande Conservancy District; and that the right is secondary only to the ancient systems of irrigation which have been in operation for many centuries at Isletta, Socorro, and other native settlements along the river.

Water Losses Reduced by Clearing Trees

The plan of development calls for an extensive program of timber clearing by which the willows and cottonwoods will be removed from the great majority of the area to be improved. These are extravagant users of water; therefore, this clearing will result in a material saving, since willows and cottonwoods occupy more than a majority of the lands at present. The willows removed in clearing this land will be fully utilized in constructing the woven willow fences along the river banks to aid in preventing further erosion.

Water for the Flooded Areas to be Developed by Drainage

Plans have been made to supply water to the proposed ponds and marshes in the low-lying portions of the refuge by excavating a series of drain ditches. It is difficult to estimate the amount of water which can be developed by such ditches but similar drains have yielded water in other areas nearby. On the Middle Rio Grande Conservancy District it is estimated that the drains pick up as much as 2 cubic feet per second per mile where the drain is 4 feet or more in depth. Under the plan of development contemplated the drains will be at least 6 feet deep and will average more than 7 feet in depth. It is intended to dig the drains as deep as possible within prescribed limits of economy, in order to avoid excessive future maintenance costs. If the drains are left shallow they will clog very quickly by the natural inflow of sand mixed with the inevitable growth of cat-tails and other undesirable plants. On the other hand if they are dug deep enough so that they will carry at least 4 feet of water, the growth of cat-tails will be retarded and the inflow of sand will be reduced. The side slopes will tend toward stabilization by virtue of the fact that the water levels in the drains will remain more constant than would be possible where the depth is more shallow.

It is observed that shallow drains develop cross currents, which set up erosion in the side banks while the velocity in deep drains is imperceptible. This eliminates the tendency toward cross currents and side erosion.

This type of development has the added advantage of providing open water for the birds during freezing weather and of making an ideal habitat for the several species of ducks which will remain to nest during the summer months. Many ducks which would otherwise journey farther north will be induced to breed within the Refuge.

Units of Project to be Surrounded by Border Dikes or Levees

The plan of development as outlined calls for a dike of moderate proportions around each unit of the project. In most cases the height of the embankment will be such as to provide a means by which the units can be flooded. This will make it possible first of all to cover the agricultural lands with water during the winter months when losses from evaporation are small. The deeper soils may be moistened to such an

extent that they will produce a crop without further irrigation or at most they will require not to exceed one additional irrigation before maturity. This method of operation is conducive to the minimum loss of irrigation water by evaporation and the maximum production per unit volume of water applied.

The borders around the individual units have a more important use than the one mentioned. As has been stated earlier in this report, there is a strong tendency for water-covered areas to develop an excessive growth of cat-tails and other marsh weeds which are detrimental not only because of their extravagant use of moisture but also because they limit the amount of open water and reduce the area where beneficial duck foods may grow. In order to control this situation a means of completely draining any or all of the units of the project is being provided for the purpose of killing cat-tails and other objectionable marsh weeds. To complete the elimination of undesirable plants, the units which have been drained can be kept dry for a period of from one to two seasons. Because of these needs, the plan provides for a rotation of the water-covered units or ponded areas from time to time. In this way certain units which are normally devoted to the production of agricultural crops may be held under water or partly under water for a period of from one to three years, during which time a portion of the lands thus flooded may be seeded to crops which grow under water or which require a high water table. The entire project may thus be kept well within control so far as operation is concerned, and with an adequate operating equipment it may be handled by a relatively small personnel.

Clearing Trees and Brush

The dikes or borders around each unit have still another use. Before these units can be planted to agricultural crops the timbered areas must be cleared. The cost of clearing by the ordinary method with ax and grubbing hoe or even with tractor and chain would be prohibitive except where the timber is very thin. If the brush and timber are very thick, the individual trees or shrubs are relatively small in diameter. By holding water over the surface of these areas the growth may be killed, except where it is principally willow; in such cases it will be necessary to resort to cutting and to fire. There are, however, many acres which are covered by tornillo; these are killed very readily by standing water and will rot at the ground line very quickly after the water is removed. In this condition the process of clearing is relatively simple.

Equalizing Reservoirs and De-silting Basins

If these requests are granted and the plan is approved, it is intended that units 3, 4, and 6 shall be used as equalizing reservoirs and de-silting basins for the silt laden stream. These units will not carry water continuously but will be used for over-night storage and to equalize the fluctuating stream, which is the only type of delivery that can be expected on the lower end of a long canal. This method of operation will provide a means for utilizing a limited water supply to the very best possible advantage with a minimum of waste.

Water Control Structures and Dikes

The plans call for a complete set of control gates and culverts for handling the water in the drainage system as well as in the irrigation system.

Where it is necessary to carry irrigation water across an open drain, it is planned to install a culvert in the drain large enough to carry the maximum flow. In this way the irrigation canal or lateral can pass directly over the drain without interfering with its operation.

It may be observed by studying the accompanying plans that in many cases embankments are carried on both sides of the open drains. This is to prevent irrigation water from entering the drain and to enable it to function at such times as the adjacent units may be temporarily flooded. This will prevent the drains from filling with sand carried in by bank storage resulting from a fluctuating water level within the drain. In a few cases dikes or embankments are not provided on one side of an open drain. In these instances the side slopes of the drain are made very flat and the outlet from the unit is purposely limited in size so that the water surface from any ponded area which inundates an open drain may not be lowered too quickly. This will prevent the rapid inflow from bank storage and will likewise reduce the amount of sand which will be carried into the open drain. It is not intended that these units shall be filled and emptied again at very frequent intervals.

River Levee: Protection, Maintenance and Future Enlargement

Mention has been made of the desirability of holding the river within the prescribed limits. The plans as outlined above provide for the building of levees, cross jetties, and marginal fences. This subject is of sufficient importance of justify amplification.

There is unquestionable proof that the river bed is rapidly rising. It is 9 feet higher at the San Marcial bridge than it was before the reservoir was built. It is desirable therefore that the plans provide a simple and economical method of keeping pace with the river by building the levee and other protection works to higher elevations more rapidly than the river-bed is raised by the annual deposit of silt. In order to do this it is contemplated that the fence to be built along the bank of the river on either side, parallel to the levee will be raised from decade to decade. In order to raise the embankment between the willow fence and the levee a portion of the river will be turned from its course during the spring months when it is heavily laden with silt, and will be forced to flow between the fences and the levees. As the debris-laden streams filter through the black willow growth on either side they will drop their loads of silt with a corresponding rise in the elevations of the river banks.

When the soil surface between the fence and the levee has been raised to a level 2 or 3 feet lower than the top of the levee, then it is planned that an inner line of fence will be built about 50 feet

closer to the river than the levee and that the silt will be deposited between the two lines of fence. This will build the embankments to still higher levels year after year. The space between the inner fence and the levee will serve as a surface drainage ditch to carry the water which seeps through the inner fence. It will then follow along the levee to where it can be returned to the river at the lower end of the project.

In building the fences referred to it is intended that the posts shall be of black willow of varying sizes between 2 and 6 inches in diameter and from 6 feet to 8 feet long; that they shall be driven into the wet sand the same day that they are cut; and that the fencing shall be done in early spring so that the posts will take root and grow. It is further intended that the posts shall be set about 3 feet apart and that they shall be connected by weaving small willow tops back and forth from one post to the next in such a way as to make a continuous mat of woven willows. It is believed that this type of construction will serve as a protection against the meanderings of the river throughout the years to come. It is not impossible that certain portions of the fence may fail; for example, if the silt line is built to a certain height and stands at that particular level for a year or more, there will be a tendency for the willows to rot at the ground line; but this will be the exception rather than the rule since the tendency of the river-bed is upward and those parts of the fence which are buried will last indefinitely. As a further safeguard the black willow posts will grow until they become a solid mat of trees with their roots well under the water line. As the river-bed rises, new roots will be developed higher up along the trunks of the trees, thus providing for a continuation of thrifty growth.

It is proposed to control the flow into the strips between fence and dike by building temporary diversion dams across a portion of the river-bed with the wing extending far enough to catch the volume of water desired. At the intake it is proposed to build a bulkhead and admit the water through a submerged orifice, the same to serve as a safeguard against an excessive inflow from the fluctuating high water stream. There is no limit to the height to which such a levee or embankment may be built with safety, provided the strip between the fence lines is made correspondingly broad. By studying the accompanying maps it will be observed that a space of 400 feet in width is provided for this purpose. It will also be observed that the distance between the marginal embankments which are left for the river is five times the width of the minimum section which the river now occupies. This enlarged cross-sectional area is provided as a double safeguard against the possibility of failure at times of excessive flood.

There are certain limited sections where the river channel cuts in very close to the levee line. At these points it may be necessary to take additional precaution against failure due to the meandering stream. Where it is considered to be necessary to strengthen the marginal fence line, protective works suited to the existing conditions will be constructed which will serve either as a protection while the willow posts are becoming firmly established and the silting process is being carried on, or as permanent protection works as local conditions may make desirable.

Control of Torrential Floods from Arroyos on the West

In building the delivery canal for supplying water to the agricultural lands on the west side of the State Highway, it is specified that the dirt removed shall be deposited as a levee or barrier on the upper side of the channel. The slope of the surface on which the barrier will be placed will provide a natural drainage for any flood water that may flow from the relatively small drainage areas on the west. The longest of these dry arroyos is about 7 miles in length and covers a drainage area of 9 square miles. The mosaic aerial map of the area which accompanies this report indicates very clearly the nature of the watershed. Run-off from this area does not occur very frequently, but there is ample evidence of floods having come from each of the principal arroyos on the west. The west branch of the Elmendorf canal served as a temporary barrier from the floods which have occurred since it was built; the deposit has been carried up and over bank levels and has filled the canal in many places.

A portion of the area on the west side of the highway is outlined as a catchment basin for torrential floods to prevent the damage to agricultural and marsh lands which would follow if the floods are permitted to flow unrestricted through the area. The surplus water will be drawn off through the channel provided along the west margin of the highway right-of-way fence into the last unit of the project and from there into the river. However, if future experience indicates that an appreciable amount of water may be secured from the western arroyos, it may be wise to throw the water into some of the upstream units.

Ground Water Studies

In cooperation with the Bureau of Geological Survey observation wells were placed at intervals of one-quarter of a mile along each section line running east and west across the river valley. Observations of ground water levels indicate that the water-table stands all the way from zero to 8 feet below the surface, the distance varying with the topography. This situation is shown more clearly on the profiles which accompany this report. The relationship between the level of the riverbed and the corresponding soil surface on either side is also shown very clearly by these profiles. Present ground levels are indicated and the bottom of the excavation of each drain as proposed is indicated. Likewise the water levels which will ultimately be maintained within the limits of the open drain are shown. This together with the maps gives a picture of the ultimate development and shows the feasibility of securing water by drainage for maintaining a limited acreage of marsh.

Evaporation Losses

From statistics shown in detail in the appendix to this report, it is observed that evaporation from open water surface amounts to as much as 66 inches annually and that when transpiration from plants is added it is probable that the annual losses will amount to 68 or 69 inches.

The heaviest losses occur during the period from May to August. In view of the fact that many of the waterfowl which occupy the marshes in the winter months will migrate to the north in early spring and return in late fall, it is not considered to be necessary that the marsh areas be maintained at high water levels or even normal water levels during the summer, or the period of highest water loss by evaporation and by transpiration. As a matter of fact, it is contemplated that the exposed water surfaces within the drainage channels will be adequate for the birds which remain during the summer months. Because of this condition, it is estimated that the system of drains provided in the plans as outlined will furnish enough water for the development of ponded areas, exclusive of irrigation needs. As evaporation and transpiration decrease, flooded areas will be increased in size and in depth of water until there is adequate capacity for accommodating the migrant and winter resident waterfowl which arrive during the fall, winter, and early spring.

Ownership of Drainage Water

The laws of New Mexico are very explicit in the proviso that the owner of the land is entitled to the use of the drainage water which he develops on his land. This opinion has been verified by three of the leading attorneys and judges to whom the matter was referred for consideration. Because of this specific provision of law the right is claimed for developing the drainage system as indicated.

Time Required for Completion

The work outlined under this plan, with the exception of clearing the land and placing it under cultivation, can be completed under contract within the period of one year from the time work is actually started. It is estimated that approximately 50 per cent of the agricultural area can be put into condition for use during the first year; but it will require from two to four years additional time in which to complete the process of clearing unless a more expensive plan of procedure is adopted than the one outlined.

SUMMARY AND CONCLUSIONS

The proposed Bosque del Apache project is confined to the river bottom lands, comprising a total volume of 14,000 acres. After excluding certain isolated tracts and rights-of-way for highway and railroad, also an enlarged strip on either side of the river to provide a flood channel of ample capacity, the area proposed for improvement is reduced to 8,272 acres, as follows:

Area in marsh	2,379 acres
Area in agricuptural crops including food producing grasses and cover	5,893 acres
TOTAL	8,272 acres

The area in question is situated on one of the important western flyways between north and south and is required to replace the natural marsh areas along the Rio Grande which have been removed in the process of reclamation by drainage and irrigation development.

Mild winters are the rule rather than the exception, and no difficulty will be experienced in providing an adequate supply of open water each and every day of the year, except in the problem of securing the unquestioned right to its use.

As a double precaution against the possibility of closing the open water ponds by an unusual spell of low temperatures, the plan of development calls for the digging of more than 51 miles of open drain to depths greater than 5 feet. These will never freeze over even in the coldest weather.

Plans call for the planting and cultivation of nearly 6,000 acres of land in the river bottom to grains, grasses, and other foods and the planting of an area of bench land, the area to be determined by the amount of water allowed under Filing No. 3. A portion of these will be harvested to furnish a feed reserve for this and other areas in the Southwest. Portions of the stubble and the unharvested subdivisions in the river bottom are to be flooded in the fall to supply the land with moisture for the next season's crop and incidentally to make the area attractive to south-bound migrations. It is fully expected that conditions made be made sufficiently alluring so that it will hold large numbers of the birds which would normally go farther south.

Plan of Development and Operation

On account of the fact that the river-bed is four or more feet higher than land surfaces within the areas to be improved, it is necessary, first of all to protect the lands by levees. To keep the river under control and prevent it from flooding beyond its banks is a matter of prime importance.

Next in order of importance may be listed the necessity of developing an adequate water supply for maintenance of a moderate amount of marsh together with the construction of dikes and control gates for subdivision of the marsh. And third, the development of a considerable area of cultivated lands on the bench to supply food and cover on the higher ground, which calls for an adequate water supply for irrigation. The extent of the area to be determined by the amount of water available.

In keeping with this outline of procedure, it is planned to:

(1) Construct a system of levees on each side of the proposed two thousand foot river channel for the protection of the areas to be developed.

(2) Provide for present and future protection of levees

(3) Develop an extensive system of drains

  (a) To secure water for refuge purposes

  (b) To lower the water-table under agricultural areas

  (c) To obtain dirt for building dikes around the various units

(4) Border dikes around units of the project have three important uses:

  (a) They provide a ready means of flooding the agricultural lands in preparation for planting crops for food.

  (b) By providing a dike around all of the units a system of rotation may be worked out and applied which will make it possible to alternate the units which are held under water in order to dry out other units and thus control the growth of cat-tails and other undesirable marsh growth.

  (c) In clearing some of the heavily wooded areas, it would be prohibitive in expense to cut all of the timber with an ax; but, by flooding for a few months the timber and brush growth will be killed. Then, after the water is drained off, the dead trunks of trees and brush will rot at the ground line and can then be easily pushed over and burned.

(5) The development of an area of bench land to provide additional feeding grounds for migrating waterfowl and will also serve as a refuge for upland game.

Additional Notes on Water Filings

Two filings on waters of the Rio Grande, one in the amount of 97 cubic feet per second, the other 286 cubic feet per second, are being acquired with the Grant. One of these is one of the earliest of the river filings, standing as number two on the books of the State Engineer. The other filing is also of an early date.

Plans call for the irrigation of 6,000 acres of river bottom land, and such area of bench land as water may be available for. Under the State law a maximum of 3 acre feet per acre per year is allowable if the water is used beneficially.

It is planned to use about 12,000 acre feet of water for irrigation of the river bottom lands during the period from September 1 to December 31, inclusive, and spread the other 6,000 acre feet over the balance of the year. Water on the bench lands will be used in the most advantageous manner possible where it is available. The State of New Mexico Conservation Department is most anxious that provision be made for conservation of upland game and a demonstration of modern game management in connection with grazing on the same area.

Equalizing Reservoirs

Being at the lower end of the Middle Rio Grande Conservancy District, from which system it is planned to secure the water for irrigation, a wide fluctuation in volume of delivery day by day and week by week may be expected. To take care of this, the plans provide for an equalizing and de-silting reservoir, from which a uniform stream of clear water can be obtained for irrigation.

River Levees

In order to keep pace with the rising river-bed, a plan has been worked out for making the river build its own levees after the first lines have been built. After this initial expense, the annual increase in height can be built principally by stream action under the guidance of the regular maintenance personnel.

General Notes

The amount of development outlined to be done and the incidental costs are high of necessity, but when the importance of the location is taken into account, and when it is considered that water is the limiting factor in any refuge enterprise in the West, and that there are very few spots where water in anything like sufficient quantity is available, it sheds a different light upon the question. One is forced to the conclusion that it is better to concentrate a reasonable outlay of funds upon a good project and develop it fully than to spread a similar amount over two or more areas of lesser total value to waterfowl.

Estimate of
Proposed Improvement
of
BOSQUE DEL APACHE MIGRATORY WATERFOWL REFUGE

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East of Santa Fe Railroad and west of Rio Grande:

Levee and jetties				
Earthwork . . .	552,800 cu. yds.	@	$0.08	$ 44,224.00
Rock in place .	11,200 " "	@	1.00	11,200.00
Brush fence . . .	22,800 ft.	@	0.10	2,280.00
	10,000 ft.	@	0.30	3,000.00
Interior dikes and drains				
Earthwork . . .	823,600 cu. yds.	@	0.08	65,888.00
Structures				
Gates	$2,634.00			
Pipe	2,680.00			
Placing pipes and gates and building headwalls, 88 structures @ $30.00 each . . .	2,640.00			
Special structures	550.00			
	$8,504.00			8,504.00
Clearing land for cultivation 2,873 acres @ $30.00 per acre . . .				86,190.00
Preparation of land for irrigation 2,873 acres @ $5.00 per acre . . .				14,365.00
			TOTAL	$235,651.00
Contingencies, engineering and supervision, 15%				35,348.00
			TOTAL	$270,999.00

West of Santa Fe Railroad:

Interior dikes and drains		
Earthwork . . . 150,000 cu. yds. @ $0.08		$ 12,000.00
Structures		
Gates	$240.00	
Pipe	389.00	
Special structures .	400.00	
Placing of pipe and gates and building headwalls, 12 structures @ $30.00	360.00	
	$1,389.00	1,389.00
Clearing land for cultivation		
434 acres at no cost		
Preparation of land for irrigation		
434 acres @ $5.00 per acre		2,170.00
		$15,559.00
Contingencies, engineering and supervision, 15%		2,334.00
	TOTAL	$17,893.00

East of Rio Grande:

Levee and jetties		
Earthwork . . . 305,400 cu. yds. @ $0.08		$24,432.00
Rock in place 8,400 cu. yds. @ 1.00		8,400.00
Brush fence . . . 26,400 ft. @ 0.10		2,640.00
Interior dikes		
Earthwork 55,200 cu. yds. @ 0.07		3,864.00
Structures		
Gates	$630.00	
Pipe	864.00	
Placing pipe and gates and building headwalls, 17 structures @ $30.00	510.00	
Spillways in place . .	400.00	
Val Verde Canal intake	800.00	
	$3,204.00	3,204.00

East of Rio Grande (continued):

Clearing land for cultivation 1,454 acres @ $30.00 per acre		$43,620.00
Preparation of land for irrigation 1,454 acres @ $5.00 per acre		7,270.00
		$93,430.00
Contingencies, engineering and supervision, 15%		14,015.00
	TOTAL	$107,445.00

Summary

East of Santa Fe Railroad and west of Rio Grande	$270,999.00
	17,893.00
	107,445.00
GRAND TOTAL	$396.337.00

Photographs

Photographs illustrate conditions at Bosque del Apache in 1936

No. 1 Looking up river from point of land at south extremity of Unit 44, in April 1936. View shows water backing up from river to bridge at "4 F". Sand bags four feet high required to prevent river water from flowing back through bridge opening into Unit 44.

No. 2 Looking down river from same point of land as No. 1. Looking toward dense Bosque on east side, Unit 48.

No. 3 View along east side of railroad levee about point "4 E". Looking southeast, April 1936.

No. 4 Interior of Unit 40 in April 1936

No. 5 Looking northeast across Unit 42 in April 1936

No. 6 Similar position to No. 5 except looking up track, in May 1936, when river was up and Units 40, 41, and 43 were under water.

No. 7 Conservancy District drain along east side of Unit "A B", May 1936. Examining inflow from marsh and Bosque on west side of drain.

No. 8 View near outlet of river side drain, May 1936, showing overflow caused by river backing up through mouth of drain, at a point about 1000 feet north of outlet.

Nos. 9 and 10

Panorama of San Marcial from the river heights on the west. Note water tank in distance on No. 9. River runs along cottonwood area beyond the railroad. The swamp in foreground is seepage and overflow water, occuping the streets of the old town. No outlet back to river for this water. It is rapidly growing into a solid cat-tail swamp. Remnants of old town in foreground and on extreme right.

No. 11 View in heart of old town of San Marcial

No. 12 View in heart of old town of San Marcial

No. 13 Another view in San Marcial

No. 14 The "last stand" in San Marcial. The old hotel is completely surrounded by water, April 1936.

Nos. 15 & 16

Two views near the point of diversion to Elmendorf canal. Looking upstream toward San Antonio Bridge. Point of diversion is on left extremity of No. 16, just beyond the bridge.

No. 17 Mapping under difficulties, with a plane table

No. 18 Interior of Unit 4 in the edge of the dense timber (Bosque)

No. 19 A portion of the Bosque. Northern part of Unit 4.

No. 20 Deep well, warm flowing water, southeast of center, Unit 37.

No. 21 One of the coves making up the 800 acres of river valley land being excluded from east side portion of the proposed Migratory Waterfowl Refuge.

No. 22 Intake to Val Verde canal on east side. Looking upstream from a point near "42 J".

No. 23 East bank of Rio Grande near north boundary of project, opposite south end of Unit 4.

No. 24 River bank revetment on west bank of river, a short distance above north boundary of Bosque del Apache, placed for protection of the Conservancy District's Canal and drain.

No. 25 Intake to San Antonito canal. The rising river bed has deflected the stream to the opposite bank and has built a huge sand-bar across the canal intake. These and numerous other laborers are endeavoring to shovel a ditch through the bar of quicksand. It is too boggy for horses and the men have to keep moving to avoid sinking.

No. 26 This photo taken next morning after that shown above (No. 25). Note that the rising river has destroyed the previous day's work. Incidentally it required two weeks of hard labor before the task was completed.

No. 27 Rio Grande from a point immediately above the intake of San Antonito Canal, looking across river towards San Antonio.

No. 28 San Antonio bridge showing height to which silt has raised the river bed. When this picture was made, April 1936, there was no clearance beneath the east half of the bridge. Old natives of the settlements state that when the bridge was built there was a clearance of more then ten feet.

No. 29 Under the mistletoe in the Bosque

Estimate of Monthly Distribution of Irrigation
Demand for Middle Rio Grande Conservancy
District Lands, Report of 1928

January	0%
February	0%
March	3%
April	17%
May	19%
June	19%
July	19%
August	14%
September	8%
October	1%
November	0%
December	0%
	100%

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Proposed System of Distribution of Irrigation Water
for the

BOSQUE DEL APACHE PROJECT

The proposed distribution of use on the Refuge would be quite different from that on Middle Rio Grande Conservancy District lands. The Biological Survey would expect to use between 7,500 and 8,000 acre feet during the three summer months but the bulk of the water would be used during the fall months. Thus a greater part of the volume would be applied during a period when evaporation losses are not so high.

SUPPLEMENTAL DATA

Average Annual Precipitation at San Marcial, New Mexico
Elevation 4447
U. S. Weather Bureau Summary of average monthly precipitation, in inches
1858 to 1930 record

Month	0.33
February	0.34
March	0.35
April	0.32
May	0.38
June	0.57
July	1.82
August	1.80
September	1.44
October	0.84
November	0.51
December	0.43
Average year	9.13

Minimum years, 1901 with 1.08 inches of precipitation, and 1917 with 3.25 inches.

Maximum years, 1859 with 24.58 inches of precipitation, and 1905 with 21.79 inches.

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Annual Precipitation at San Marcial and Socorro, New Mexico for the Period January 1931 to December 1935 inclusive

	Precipitation, in inches	
Year	San Marcial	Socorro
1931	11.30	15.90
1932	10.03	10.30
1933	7.89	12.42
1934	5.50	6.79
1935	8.36	12.14
Average	8.62	11.51

The normal precipitation for San Marcial is 9.13 inches per annum and for Socorro is 10.13 inches per annum. The record for the past five years indicates that the region has had about normal precipitation for this period.

San Marcial is located five miles South of the South line of the Bosque del Apache Grant and Socorro is located thirteen miles North of the North line of the Grant.

Average Maximum and Minimum Monthly Temperatures at San Marcial, New Mexico from U. S. Weather Bureau Summary, 1858-1930

Month	Temperatures	
	Maximum	Minimum
January	53.9	22.5
February	60.1	27.7
March	69.0	33.2
April	77.0	40.0
May	85.2	47.6
June	93.6	56.4
July	93.9	62.4
August	93.1	61.0
September	86.0	53.2
October	75.4	40.5
November	63.6	29.8
December	52.0	21.8
Average annual	75.2	41.3

The lowest recorded minimum is -9

Inspection of daily temperature records indicates that there are generally from 90 to 100 days each year with minimum temperatures below freezing but only on rare occasions do temperatures stay below freezing for a full day. The matter of ice conditions in the valleys of central and eastern New Mexico was discussed with the U. S. Weather Bureau official observer at Roswell, N. M. He stated that although extremes of low temperatures were more common at Roswell than at San Marcial, usually the ice frozen at night on ponds and other still waters there, thaws completely before noon the next day. Soils do not freeze sufficiently to interfere with plowing. Running streams do not freeze over and shallow ponds freeze only on the rare occasions when freezing temperatures hold for several days on end.

Other Climatological Data Affecting the Proposed Development

Humidity in the vicinity of San Marcial and Socorro, New Mexico. Averages 45% to 50% and sunshine 70% to 80%. There is considerable wind during spring and early summer. The prevailing winds are from the Southwest.

The last killing frost in the spring may occur as early as March 21st or as late as May 7th. The first killing frost in the fall may occur as early as September 23rd or as late as October 21st. The average growing season lasts from 190 to 200 days.

Average Monthly Discharge of the Rio Grande
at San Marcial, New Mexico
Period January 1931 to December 1934 inclusive

Average monthly discharge		Percentage of annual
January	719 sec. ft.	6%
February	866 " "	7%
March	902 " "	8%
April	1404 " "	12%
May	2532 " "	22%
June	1978 " "	17%
July	896 " "	7%
August	558 " "	5%
September	584 " "	5%
October	362 " "	3%
November	353 " "	3%
December	647 " "	5%
Average	983 " "	100%

Total Discharge of the Rio Grande at San Marcial,
New Mexico

Period January 1931 to December 1934 inclusive

Year	Discharge in acre feet
1931	489,790
1932	1,399,460
1933	716,560
1934	244,489
Average	712,575

The average annual discharge for this four-year period is estimated to be approximately 70% of a 30 year average annual discharge that may be anticipated under present conditions on the Rio Grande. Between 50% and 60% of the average annual discharge occurs in the period covered by April, May and June.

The minimum discharge of the Rio Grande measured at San Marcial has been as low as zero for 56 days in 1931, and 7 days in 1932; 1.6 second feet flow for one day in 1936; and zero for 78 days in 1934. These low discharges occurred in June, July, August, and September.

The greatest recorded flow at the same station occurred September 24, 1929 when the peak flow was estimated to have been 47,000 second feet. Records on discharge at San Marcial since 1895 are available.

Average Monthly Temperature, Precipitation and Evaporation at Elephant Butte Dam, from U. S. Weather Bureau 1930 Summary

Temperature in degrees, precipitation and evaporation in inches.

Month	Average temperature	Precipitation	Evaporation
January	40.6	0.26	2.735
February	45.4	0.35	4.315
March	51.1	0.41	7.619
April	58.4	0.43	10.300
May	67.2	0.36	12.903
June	76.6	0.70	14.038
July	78.7	2.04	11.897
August	77.2	2,30	10.374
September	71.2	1.40	8.727
October	60.4	0.77	7.239
November	48.3	0.47	3.910
December	39.4	0.59	2.655
Average annual	59.6	10.08	96.709

The Elephant Butte Dam is located 60 miles South of the Bosque del Apache Grant and the weather station had an elevation of 4,265 feet above mean sea level. The length of the temperature record given above is 33 years, the precipitation record 42 years and the evaporation record 14 years.

The year of maximum evaporation is 113% of the average. The month of maximum evaporation (June) is 121% of the average June. Evaporation records are from a Weather Bureau standard land pan.

Table of Approximate Quantities Used in Determining SIZE OF GATES AND CULVERTS ..t Inlets and Outlets of the Units and in Handling and Controlling Drainage Water

Diameter	Area	For a velocity of 20 cubic feet per second: Velocity	Required Head	For a velocity of 10 cubic feet per second: Velocity	Required Head
12"	0.7854 sq.ft.	25.47 ft.per sec.	20.2 ft.	12.74 ft.per sec.	5.0 ft.
18"	1.7671 " "	11.32 " " "	4.0 "	5.66 " " "	1.0 "
24"	3.1416 " "	6.37 " " "	1.4 "	3.18 " " "	0.4 "
30"	4.9087 " "	4.07 " " "	0.5 "	2.04 " " "	0.2 "

PROBABLE AVERAGE YEARLY WATER CONSUMPTION IN THE BOSQUE DEL APACHE UNDER VARIOUS CONDITIONS

Taking the ratio of evaporation as recorded by the United States Weather Bureau standard land pan to that of the evaporation from a free water surface as 1.457 to 1.0, the average monthly evaporation from free water surfaces on the Refuge as determined from the Elephant Butte records is as follows:

Month	Evaporation in inches	Precipitation in inches	Net Loss in inches
Jan.	1.88	0.33	1.55
Feb.	2.96	0.34	2.62
Mar.	5.23	0.35	4.88
Apr.	7.07	0.32	6.75
May.	8.86	0.38	8.48
June	9.65	0.57	9.08
July	8.17	1.82	6.35
Aug.	7.12	1.80	5.32
Sept	5.99	1.44	4.55
Oct.	4.96	0.84	4.12
Nov.	2.68	0.51	2.17
Dec.	1.82	0.43	1.39
Yearly average	66.39	9.13	57.26 or 4.77 feet

Evaporation and transpiration losses from lands with high ground water and covered with heavy growth of willows, cottonwoods, cat-tail, and marsh grasses during the growing season equals, and during part of the time exceeds, the evaporation from a free water surface.

Assuming an average of these areas, the losses will vary throughout the year approximately as follows:

Month	Evaporation and Transpiration in inches	Precipitation in inches	Net Loss in inches
Jan.	0.94	0.33	0.61
Feb.	1.48	0.34	1.14
Mar.	2.61	0.35	2.26
Apr.	6.76	0.32	6.44
May.	8.50	0.38	8.12
June	9.21	0.57	8.64
July	7.81	1.82	5.99
Aug	6.81	1.80	5.01
Sept	5.74	1.44	4.30
Oct.	4.76	0.84	3.92
Nov.	1.34	0.51	0.83
Dec.	0.91	0.43	0.48
Yearly average	56.87	9.13	47.74 or 3.98 feet

Swamp areas with water covering surface and existing sloughs with large amount of aquatic growth such as cat-tails and swamp reeds and grasses will probably evaporate and transpire as high as 90.05 inches per year and the net loss will be 80.92 inches or 6.74 feet.

Water Consumption Under Existing Conditions of 3,160 Acres Within Limits of Proposed Protection Levee on West Side of Rio Grande in the Bosque del Apache.

300 acres of sloughs	at 6.74 ac. ft. per acre =	1,922 ac. ft.
240 acres of swamp with surface water	at 6.74 ac. ft. per acre =	1,618 ac. ft.
2,620 acres of heavy growth of willows, cottonwoods, or marsh grasses or combination	at 3.98 ac. ft. per acre =	10,427 ac. ft.
3,160 acres		13,967 ac. ft.

Water Consumption Under Proposed Conditions of 3,160 Acres Within Limits of Proposed Protection Levee on West Side of Rio Grande in the Bosque Del Apache.

100 acres of open drains	at 4.77 ac. ft. per acre =	477 ac. ft.
440 acres of permanent ponds	at 4.77 ac. ft. per acre =	2,099 ac. ft.
1,620 acres of ponds flooded for 12 months each year	at 4.77 ac. ft. per acre =	7,727 ac. ft.
1,000 acres of ponds flooded for 4 months each year	at 1.25 ac. ft. per acre =	1,250 ac. ft.
3,160 acres		11,553 ac. ft.

Of the lowlands on the west side of the Rio Grande, 2,600 acres are to remain in their original condition, 3,300 acres are to be cultivated, 100 acres are to be taken up with open drains, and 2,060 acres are to be flooded throughout the year. There will be little or no change in the water consumption of the acreage that will remain in its original condition. The agricultural land will be taken care of by the water right and will furnish considerable return flow, as part of these lands now have a high ground water level and irrigation net requirements will be but little more than present losses. The 1,000 acres of cultivated land that are to be flooded for 4 months of the year will require but a part of the water that is now lost each year through transpiration and evaporation from an equivalent area. The proposed flooding or ponding development will thus require less water than is now consumed on an equivalent area.

Extent of Proposed Permanent Open Drains, Water Developed, and Extent of Ponding Requirements

Extent of Proposed Permanent Open Drains

	Miles
Between the Railroad and the Rio Grande	34.1
West of the Railroad	12.1
East of the Rio Grande	4.8
Total	51.0

The interior drains of the Socorro area develop from $1\frac{1}{2}$ to 3 second feet per mile varying with the seasons. It is reasonable to assume that the proposed drains in the Bosque del Apache will average about 6/10 second feet per mile of drains as a minimum. These drains will be relatively close together, will not have available the equivalent of a heavily irrigated tributary area, and for these reasons will not average nearly as high a discharge per mile as those in the Socorro area.

The proposed drains will thus furnish 30 cubic feet per second of drainage water which will be available for ponding. Thirty second feet are equivalent to 1,800 acre feet each month.

Water Used per Acre and per 1,000 Acres

Month	Net Use		
	Depth in inches	in acre feet per acre	in acre feet per 1,000 acres
Jan.	1.55	0.13	130
Feb.	2.62	0.22	220
Mar.	4.88	0.41	410
Apr.	6.75	0.56	560
May.	8.48	0.71	710
June	9.08	0.76	760
July	6.35	0.53	530
Aug.	5.32	0.44	440
Sept	4.55	0.38	380
Oct.	4.12	0.34	340
Nov.	2.17	0.18	180
Dec.	1.39	0.11	110
	57.26	4.77	4,770

Eighteen hundred acre feet will scarcely meet the requirements of 2,379 acres of ponds for the month of maximum evaporation (June) in the average year, and in dry years the ponds may be materially depleted during the summer. During other months, September, for example, the requirements of existing ponds will be less per acre, but sufficient drainage water may not be available for rapidly flooding cultivated areas in preparation for the fall migration.

Areas in Units East of Rio Grande

Unit	Water over 2 ft. deep	Water under 2 ft. deep	Natural ground	Cultivated ground
45				55
46				230
47				345
48-A		17	29	
48-B	39	151	116	
49-A				218
49-B				155
50-A				294
50-B				157
51-A		96	151	
51-B		15	67	
	39	279	363	1,454

Total area in Units East of Rio Grande 2,135 Acres

Areas in Units West of State Highway

Unit	Water over 2 ft. deep	Water under 2 ft. deep	Natural ground	Cultivated ground
1				82
11-A				169
11-B				86
21	8	137	23	60
29	12	50	11	
36		6	12	
39	8	33	21	37
42		17	8	
44	22	20	6	
	50	263	81	434

Total area in Units West of State Highway 828 Acres

Areas in Units West of Rio Grande
and East of A. T. & S. F. R. R.

Areas in Acres

Unit	Water over 2 ft. deep	Water less 2 ft. deep	Natural ground	Cultivated ground
2-A				45
2-B				58
3		56	24	
4	129	64	30	
5				63
6	53	36	16	
7-A	2	62	21	
7-B				61
8				107
9	125			
10				86
12-A				146
12-B	24	28	4	
13			16	380
14-A & 14-B	2	146	69	
15	6	65	31	
16				153
17				90
18				37
19	24	96		
20	3		12	243
22		40	28	
23	25	126	40	
24-A	10	84	64	
24-B				96
25				498
26				35
27-A & 27-B		6		228
28	10	15	15	
30		10	44	
Carry fwd.	413	834	414	2,326

Unit	Water over 2 ft. deep	Water less 2 ft. deep	Natural ground	Cultivated ground
Brot fwd.	413	834	414	2,326
31		55	25	
32		47	77	170
33			6	122
34			23	112
35		98	28	
37			8	93
38		66	24	
40	16	56	32	3
41	42	47	15	47
43	11	63	36	
Total	482	1,266	688	2,873

Total area in Units West of Rio Grande and East of A. T. & S. F. R. R. 5,309 Acres

Total all Units 8,272 Acres

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Summaries of Areas

Location	Water over 2 ft. deep	Water less 2 feet deep	Natural ground	Cultivated ground
Between RR and River	482	1,266	688	2,873
West of RR	50	263	81	434
East of River	39	279	363	1,454
Sub totals	571	1,808	1,132	4,761
		571		
		2,379		1,132
Total farming area				5,893
Total marsh area				2,379
Grand total within area of development				8,272

Summary Showing Classification of Agricultural Lands According to Vegetative Cover, With Kinds and Amount of Timber in the Area Between the Railroad and the River.

Salt grass	1,170.0	acres
Salt grass and scattered tornillo, cottonwood, and willow less than 10 to the acre . .	144.0	"
Salt grass and tornillo, cottonwood, and willow from 10 to 700 to the acre.	355.0	"
Tornillo, 10 to 550 to the acre	720.0	"
Total	2,389.0	acres

The above summary is taken from an estimate which is noted on a blue print of the area in question. This is available for detailed study by those who may wish to obtain further information.

This classification included only lands intended to be cleared for agricultural development.